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Geographical Variations in Spadix Color of *Symplocarpus renifolius* (*Araceae*) in Honshu, Japan

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Variation of spadix color in *Symplocarpus renifolius* Schott ex Tzvelev (= *S. foetidus* var. *latissimus*) is observed in central Honshu, Japan. The spadix of the species is mostly red-purple in the Sea of Japan side regions from southern Yamagata Pref. to Shiga Pref. while that is usually creamy yellow in the Pacific side regions from southern Tochigi and Gunma Pref. to central-southern Nagano Pref. The geographical boundary between the above two groups in different color patterns of the spadices is nearly corresponding with the line of annual maximum snow depth over 50 cm. The former having mostly red-purple spadix occur within the area of annual maximum snow depth over 50 cm.

Key words: *Araceae*, geographical variation, spadix color, *Symplocarpus renifolius*, *Symplocarpus foetidus* var. *latissimus*.

The genus *Symplocarpus* Salisb. ex W. P. C. Barton (*Araceae*) is distributed in Eastern and North Asia, and North America. It consists of five species, *Symplocarpus foetidus* (L.) Salisb. ex W. P. C. Barton, *S. renifolius* Schott ex Tzvelev (= *S. foetidus* (L.) Salisb. ex W. P. C. Barton var. *latissimus* H. Hara), *S. nipponicus* Makino, *S. nabekuraensis* Otsuka & K. Inoue and *S. egorovii* N. S. Pavlova & V. A. Nechaev (Otsuka 2002, Otsuka et al. 2002, Pavlova and Nechaev 2005). In Japan, three species, *S. renifolius*, *S. nipponicus* and *S. nabekuraensis*, are recognized (Otsuka et al. 2002). *Symplocarpus renifolius* is distributed in Honshu (east of Chugoku District) and Hokkaido in Japan, and Amur, Sakhalin and Ussuri in Russia (Ohwi 1953, Okuyama 1982). The flowers of *Symplocarpus* species are bisexual and protogynous, and consist of four tepals, one pistil and four stamens. The spadix is oval and densely bears many flowers (Ohwi 1953, Ohashi 1982).

In the genus *Symplocarpus*, spathe color has been recognized as a taxonomical character. Spathes of *S. renifolius* are large and envelop the spadix, and spathe color is usually red-purple, but rarely yellow-white to yellow-green. The latter form is called "Ao-zazenso", *S. foetidus* f. *viridispathus*, nom. nud. (Makino 1940). In *S. nipponicus*, we can find yellow-white to yellow-greenish spathe very rarely. These forms are called "Midori-himezazenso", *S. nipponicus* f. *viridispathus* J. Ohara (Ohara 1985). The spathe color of *S. nabekuraensis* is almost red-purple and rarely lighter in color, but is never yellow-white to yellow-green (Otsuka unpublished).

In contrast to the spathe color the spadix and flower color have not been paid attention as characteristics. In previous studies, the first

Table 1. Localities investigated and the ratio of spadix color types of *Symplocarpus renifolius*

No.	Locality	Altitude (m)	Area (m^2)	Number of individuals (N)	Ratio of the spadix color types (%)		
					Red-purple	Intermediate color	Yellow
1	Oguni-machi, Kawaratuno, YAMAGATA	350	200	30	83.3	13.3	3.3
2	Oguni-machi, Iidetamakawa, YAMAGATA	270	400	30	60	23.3	16.7
3	Shirakawa-shi, Karameyama, FUKUSHIMA	350	225	36	27.8	38.9	33.3
4	Shirakawa-shi, Shirasaka, FUKUSHIMA	380	135	10	60	40	0
5	Minamiaizu-machi, Miyatoko, FUKUSHIMA	810	100	21	76.2	23.8	0
6	Sado-shi, Mt. Donden, NIIGATA	790	370	54	55.6	37	7.4
7	Sado-shi, Mt. Donden Aoneba, NIIGATA	750	300	46	63	30.4	6.5
8	Sado-shi, Mt. Kinpoku, NIIGATA	1,020	400	52	84.6	15.4	0
9	Uonuma-shi, Koide, NIIGATA	97	200	80	78.8	18.8	2.5
10	Myoko-shi, Arai, Mt. Ôkenashi, NIIGATA	380	40	35	71.4	17.1	11.4
11	Otawara-shi, Kitakanamaru, TOCHIGI	185	700	46	78.3	17.4	4.3
12	Nakagawa-machi, Umezo, TOCHIGI	149	600	88	44.3	36.4	19.3
13	Nikko-shi, Kinugawa-Ryûôkyo, TOCHIGI	420	250	50	56	24	20
14	Nikko-shi, Imaichi-Iwasaki, TOCHIGI	210	300	34	50	35.3	14.7
15	Sano-shi, Kitsugihara, TOCHIGI	395	400	37	16.2	27	56.8
16	Sano-shi, Subana, TOCHIGI	200	150	34	44.1	23.5	32.4
17	Katashina-mura, Hanasaki, GUNMA	975	500	69	62.3	34.8	2.9
18	Katashina-mura, Hariyama, GUNMA	1,095	500	73	52.1	35.6	12.3
19	Fujimi-mura, Numanokubo, GUNMA	437	600	94	9.6	35.1	55.3
20	Kusatsu-machi, Kusatsu, GUNMA	990	600	66	13.6	48.5	37.9
21	Yokoze-machi, Ashinokubo, SAITAMA	494	200	31	6.5	25.8	67.7
22	Chichibu-shi, Arakawa, SAITAMA	460	400	39	20.5	35.9	43.6
23	Koshu-shi, Hirasawa, YAMANASHI	761	100	49	16.3	32.7	51
24	Hokuto-shi, Takane, YAMANASHI	1,330	28	59	6.8	23.7	69.5
25	Hokuto-shi, Kaikoizumi, YAMANASHI	1,060	500	70	20	28.6	51.4
26	Koumi-machi, Koumihara, NAGANO	1,060	30	78	9	21.8	69.2
27	Minamiaiki-mura, Sanjaku, NAGANO	1,060	25	85	12.9	18.8	68.2
28	Nagawa-machi, Takayama, NAGANO	1,430	18	72	4.2	26.4	69.4
29	Fujimi-machi, Nyûgasa, NAGANO	1,750	150	34	8.8	17.6	73.5
30	Suwa-shi, Aruga, NAGANO	1,060	20	50	42	26	32
31	Kiso-mura, Sakai-tôge, NAGANO	1,300	200	56	5.4	23.2	71.4
32	Ina-shi, Niiyama, NAGANO	950	400	42	7.1	14.3	78.6
33	Komagane-shi, Akaho, NAGANO	660	150	43	30.2	16.3	53.5
34	Takamori-machi, Tazawa, NAGANO	790	200	23	4.3	13	82.6
35	Iida-shi, Yamamoto, NAGANO	680	200	51	3.9	17.6	78.4
36	Achi-mura, Haranotaira, NAGANO	690	150	45	6.7	11.1	82.2
37	Namiai-mura, Jibuzaka, NAGANO	1,190	150	85	5.9	24.7	69.4
38	Anan-mach, Niino, NAGANO	800	200	47	12.8	10.6	76.6
39	Hakuba-mura, Kirikubo, NAGANO	770	50	65	70.8	20	9.2
40	Hakuba-mura, Iimori, NAGANO	770	40	59	76.3	15.3	8.5
41	Ômachi-shi, Yanaba, NAGANO	890	60	64	81.3	9.4	9.4
42	Azumino-shi, Horigane, NAGANO	730	105	49	57.1	26.5	16.3
43	Tateyama-machi, Tateyama, TOYAMA	640	300	37	64.9	16.2	18.9
44	Toyama-shi, Yatsuo-koinami, TOYAMA	480	220	22	77.3	18.2	4.5
45	Nanto-shi, Taira, TOYAMA	590	90	38	73.7	15.8	10.5
46	Kanazawa-shi, Uchikawa-damu, ISHIKAWA	290	300	38	68.4	21.1	10.5
47	Hakusan-shi, Shiramine, ISHIKAWA	570	600	27	63	18.5	18.5
48	Hida-shi, Miyakawa, GIFU	980	200	65	58.5	26.2	15.4
49	Takayama-shi, Kotori, GIFU	1,017	50	13	76.9	7.7	15.4
50	Gujô-shi, Hirugano, GIFU	880	300	68	61.8	11.8	26.5
51	Ôno-shi, Kamiuchinami, FUKUI	550	400	28	64.3	17.9	17.9
52	Ôno-shi, Kumokawa, FUKUI	485	900	32	78.1	15.6	6.3
53	Takashima-machi, Imazu, SHIGA	114	180	52	61.5	25	13.5

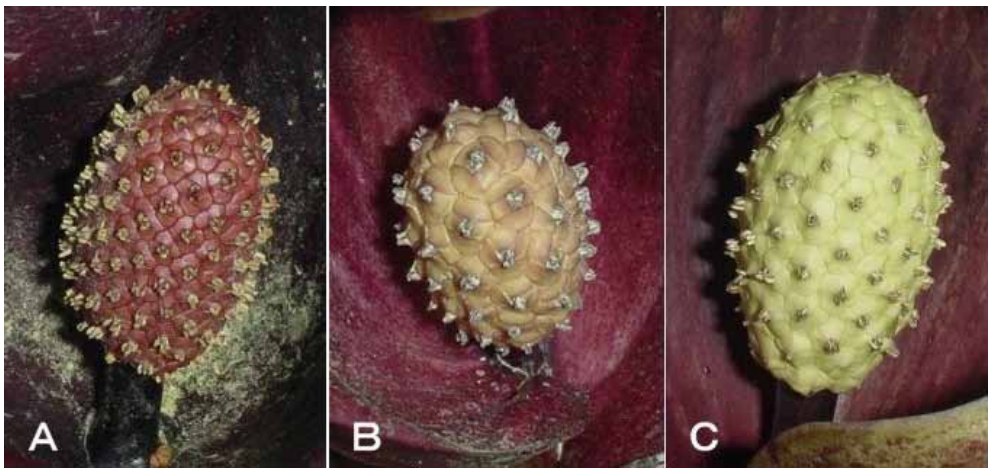

Fig. 1. Three types of spadix color in of *Symplocarpus renifolius*. A. Red-purple type. B. Intermediate color (light pink color) type. C. Yellow type.

author researched variation of the spadix color in *S. renifolius* in Nagano Prefecture in detail (Otsuka 2005). He found that their colors are mainly red-purple in Hakuba Village, northern Nagano Prefecture, but are mainly yellow in Iida City, southern Nagano Prefecture. The data suggest that geographical variations of spadix color in *S. renifolius* exist (Otsuka 2005). The present researches reveal the color variations throughout Honshu, Japan.

Study sites and Methods

We conducted field surveys on 53 study sites (Table 1) in 2009 and 2010 in Honshu, and in 2005 in Nagano Prefecture, in the flowering season (from February to May, partially June). We recorded the altitude, area of the sites and number of the individuals, and observed the spadix color (flower color) of the individuals in flowering stage as many as possible.

Spadix color of *S. renifolius* is slightly lighter in preanthesis period, but it becomes mature color by the female stage and is constant during male stage. In the field, therefore we observed flower color in the flowering stage on and after female stage. In study sites, we sometimes checked the color using field-binoculars.

Results and Discussion

Although the lightness and darkness of the spadix color varied widely, we were able to classify the color into three types, namely, red-purple, intermediate color (light pink) and yellow (Fig.1). We observed the color of more than fifty individuals in each site where possible, but in small or inaccessible populations, we recorded the color of the fewer ones. We show the spadix color composition of 53 study sites in Table 1. The ratio of red-purple spadices was over 50 % at 29 sites, and the ratio of yellow ones was over 50% at 19 sites.

On the Sea of Japan side from southern Yamagata Prefecture to Shiga Prefecture, spadix color is mainly red-purple, but on the Pacific side from south-western Tochigi Prefecture to central and southern Nagano Prefecture, it is mainly yellow in color (Fig. 2). Therefore, it is clear that two geographical populations regarding the spadix color exist in Japan, i.e., red-purple color dominant Sea of Japan side type and yellow color dominant Pacific side type.

The plants having geographical vicariant variation, which are distributed separately on the different sides of the Japan Archipelago, namely Sea of Japan side and Pacific Ocean side, have been studied by Japanese botanists

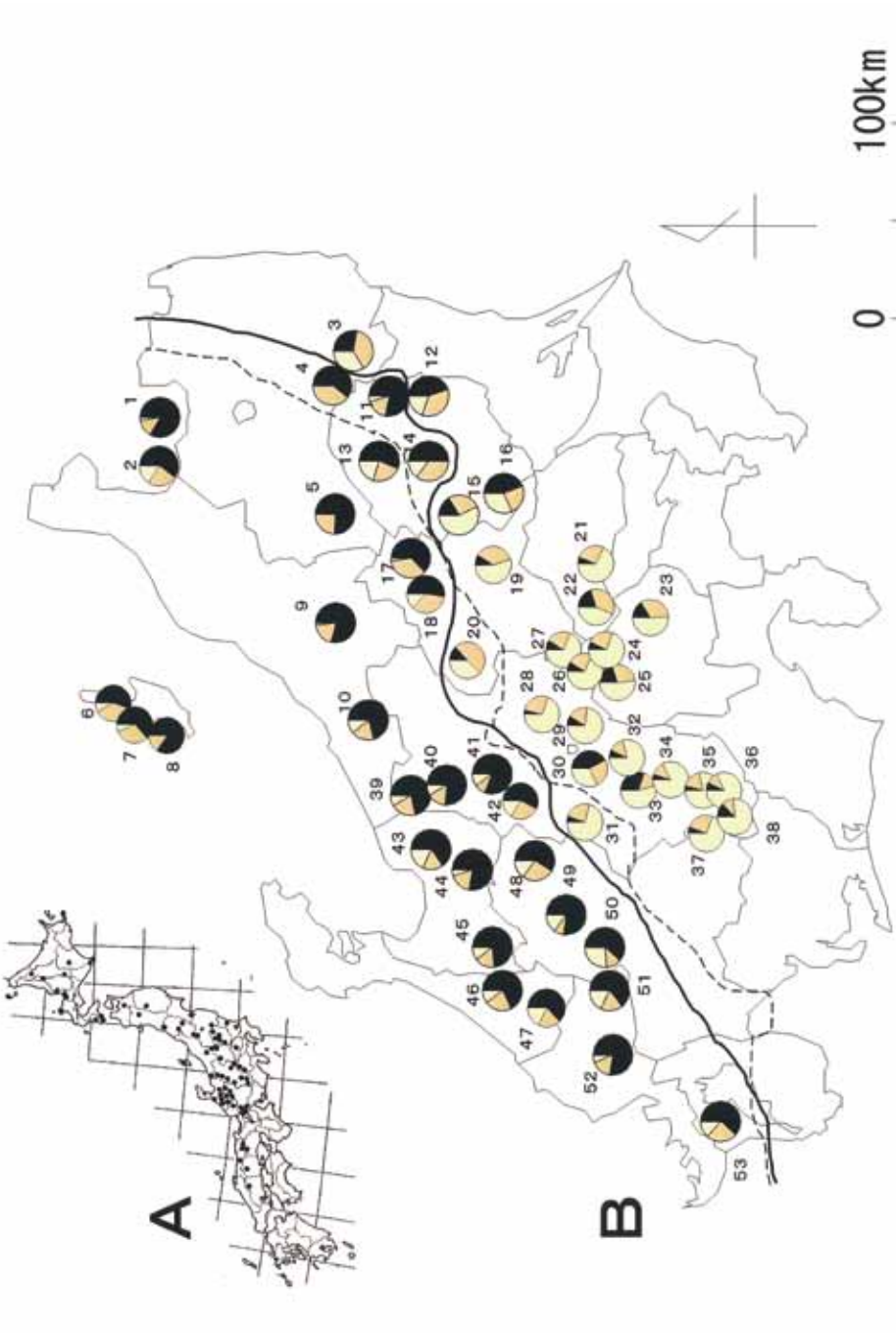

Fig. 2. A. Distribution of *Symplocarpus renifolius* in Japan (Otsuka 2002). B. Map showing the geographical variation in spadix color of *S. renifolius* in central Honshu, Japan. Circle graphs show the spadix color composition. Black. Red-purple type. Orange. Intermediate color type. Yellow. Yellow type. Numbers correspond to those appearing in Table 1. A solid line means the borderline of two types of spadix color, red-purple group (red-purple over 50 %) and yellow group. A dotted line shows the line of annual maximum snow depth over 50 cm after Fukui et al. (1985).

for a long time. For example, evergreen shrub *Cephalotaxus harringtonia* (Knight ex Forbes) K. Koch var. *nana* (Nakai) Rehder is a representative case of the intraspecific variation, and *Camellia japonica* L. subsp. *rusticana* (Honda) Kitam. shows subspecific divisions. These cases have been thought to be the shrubby form (dwarf) adaptation to the deep snow habitat in the Sea of Japan region (Hotta 1974). Also, a deciduous tree *Fagus crenata* Blume (Hagiwara 1977) and a herb the *Isodon umbrosus* group (Asano 1972**)** have broader leaves in the Sea of Japan side region against those in the Pacific Ocean side region.

On the other hand, geographical vicariant variation in flower color has very rarely been reported before. The flower color of *Geranium nepalense* Sweet shows a famous case of variation. White or light pink flowers are more common in eastern Japan and red-purple color flowers dominate in western Japan (Shimizu 1982, Akiyama 2001). *Veratrum maackii* s. l., has two groups in the flower color, purple and yellow-green flowers exist in Tohoku, while yellow-green ones are distributed mainly in the middle and southern area of Tohoku District (Takada and Kawanobe 1996).

The borderline of the two type of spadix color in *Symplocarpus renifolius* coincides well with the line of annual maximum snow depth over 50 cm (Fig. 2; Fukui et al. 1985). Consequently, the present results on spadix color variation of *S. renifolius* represented geographical vicariance pattern between the Japan Sea and Pacific Ocean sides of Japan Archipelago in relation to the snowbound depth.

Based on the research presented here, relationships between the color of spathe and spadix were clarified as follows. In plants with red-purple spathe spadices are mostly red purple and yellow-white ones are rarely found. Plants with yellow-white to yellow-greenish spathe, which are very rarely found, always have yellow-white spadices.

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大塚孝一[a, b]，須山知香[b]，植田邦彦[b]：**本州におけるザゼンソウ（サトイモ科）の花序色の地理的変異**

本州中部においてザゼンソウ *Symplocarpus renifolius* Schott ex Tzvelev (= *S. foetidus* (L.) Salisb. ex W. P. C. Barton var. *latissimus* H. Hara) の花序色の変異を調査した．花序色は山形県南部から滋賀県にかけての日本海側の地域では赤紫色が主体であったが，より太平洋寄りの栃木県南部，群馬県中南部から埼玉県，山梨県，長野県中南部にかけては黄色が主体であった．花序色は日本海側と太平洋側に分かれる 2 つの地理的な変異として認められた．2 つの地域の境界は年最深積雪 50 cm のラインとほぼ一致し，赤紫色の花序をもつグループはそのラインの北側の地域に出現した．

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